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Antibacterial Properties of Nanosized Silver Colloidal Solution on Wool Fabric

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This paper deals with the antibacterial efficacy of nanosized silver colloidal solution on the wool fabrics. Two kinds of bacteria *Staphylococcus aureus* and *Escherichia coli* were used. The morphologies, structures and antibacterial properties were characterized by using transmission electron microscopy (TEM), scanning electron microscopy (SEM), EDAX and AATCC-100 test method. Transmission electron microscopy observation of silver nano particles showed the particles were very small (6-8 nm). Scanning electron micrographs of treated fabrics indicated silver nano particles were well dispersed on the surfaces of samples. EDAX patterns showed that the per cent of nanosized silver particles increased on the surface of samples with increase concentration of colloid solutions nano silver. The results prepared of antibacterial test method indicated excellent antibacterial effect on all specimens against *S. aureus* and *E. coli*.

Key Words: Nano, Silver, Wool, Fabric, Antibacterial.

INTRODUCTION

Textiles have long been recognized as media to support the growth of microorganisms such as bacteria and fungi. These microorganisms are found almost everywhere in the environment and can multiply quickly when basic requirements such as moisture, nutrients and temperature are met. Most synthetic fibers, due to their high hydrophobic nature, are more resistant to attacks by microorganisms than natural fibers[1-3] proteins in keratinous fibers and carbohydrates in cotton can act as nutrients and energy sources under certain conditions. Soil, dust, solutes from sweat and some textile finishes can also be nutrient sources for microorganisms[1-6]. The growth of microorganisms on textiles inflicts a range of undesired effects not only on the textiles itself but also on the wearer. These effects include the generation of unpleasant odour, stains and decolouration in the fabric, a reduction in fabric mechanical strength and on increased likelihood of contamination[1-7]. Various antibacterial finishes and disinfection techniques have been developed for all types of textiles[8-10]. For a long time the chemical agents in use for controlling microorganisms range from the very simple substances such as halogen ions to the very complex compounds typified by the detergents. Many of these agents have been employed for generations while others represent the latest developments[8,9].

In recent years antibacterial agents used industrially are quarternary ammonium salts, metal salt solution and antibiotics. Unfortunately, some of these agents are toxic or poorly effective, which makes them unsuitable for application in health foods, filters and textiles for the exclusion of pollution. In contrast, silver, is a non-toxic non tolerant disinfectant that can reduce many bacterial infections significantly. As a natural renewable resource that has a number of unique properties silver now attracts the scientific and industrial interest from fields as diverse as chemistry, medicine, biotechnology, food science and textile science[11-14].

Silver nanoparticles have the properties of high surface area, very small size and high dispersion. Several studies have been undertaken to explain the antibacterial properties of silver ions toward bacteria. Polymeric or fibrous nano-composites of polymers and silver nanoparticle have been reported to have special properties[8,15]. It is believed that the mechanism of the antibacterial effect of silver ions involves shrinkage of the cytoplasm membrane or its detachment from the cell wall. As a result, DNA molecules become condensed and lose their ability to replicate upon the infiltration of silver ions. The silver ions also interact with the thiol groups of proteins which induces the inactivation of bacterial proteins[16]. In this study, the nano scaled silver particles were dispersed on the wool fabric to evaluate the antibacterial effect and its durability.

EXPERIMENTAL

The nanosized silver colloids were supplied by Narmin Shimi. Ltd. Iran at the concentration of 10000 ppm. The wool fabric samples (serge, 295 g^{-2}) were provided by Farsh Khorasan Co., Mashhad, Iran.

Methods: The concentration of colloidal silver was diluted with distilled water by 200, 400 and 800 ppm for present experimentation. The samples were padded with each concentration of colloid solutions, then were immediately dried at 120 °C and were studied the antibacterial properties of the fabric finished with the nanosized silver colloids. The samples were tested laundering durability of antibacterial effect after 5 cycles, 10 cycles and 20 cycles washing.The temperature of water was 35 °C and the washing rate was five times per minute by hand-stirring. The morphologies and sizes of the particles formed were investigated by transmission electron microscopy (TEM). We used the AATCC-100 test method (antibacterial activity assessment of textile materials) to study the antibacterial properties of fabric finished with the nanosize silver colloids. The fabrics were placed on a germ-containing agar plate and were inoculated with gram-positive (*Staphylococcus aureus*, ATCC 6538) and gram-negative (*Escherichia coli* ATCC 8099) bacteria. Specimens corresponding to untreated controls of the same material were placed in intimate contact with the nutrient agar, which previously had been streaked with inoculums of the test bacterium. After incubation for 24 h, we evaluated the antibacterial properties of both the untreated fabric and the treated fabrics.

$$\text{Per cent reduction of bacteria (\%)} = \frac{(A - B)}{A} \times 100$$

A = The number of bacteria on the untreated fabric after 24 h; B = the number of bacteria on the antibacterial treated fabric after 24 h.

The dispersibility and affinity of the silver nanoparticles on the surface of wool fabrics were estimated by using scanning electron microscopy (SEM) and elemental analysis was conducted with EDAX spectra. We used a sputter coater to precoat conductive gold onto the surface before measuring the microstructures.

RESULTS AND DISCUSSION

Fig 1. showed the TEM image of the nanosized silver colloid, the silver nano-particles had spherical shapes. The diameter of particles was estimated at 6-8 nm.

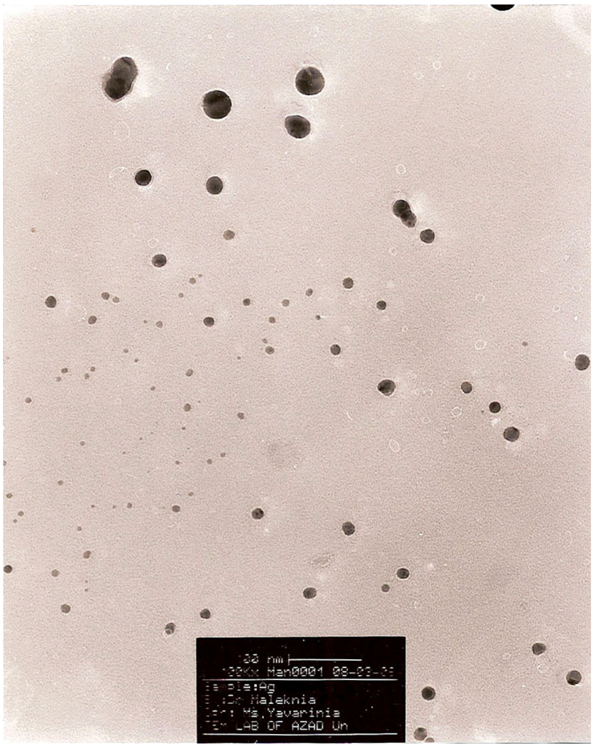


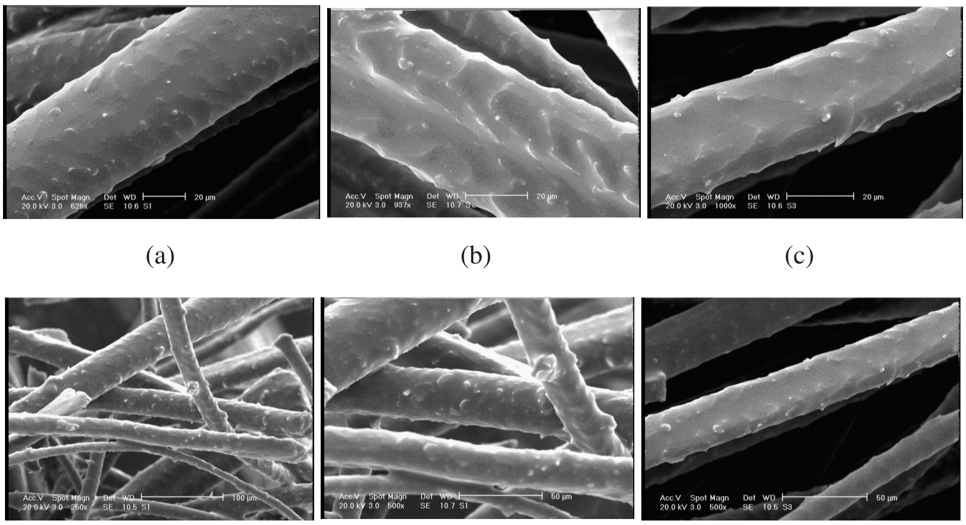
Fig. 1. TEM image of the nanosized silver colloid

Table-1 shows the antibacterial properties of fabrics treated with the nanosized silver particles in colloidal solution had excellent antibacterial effect on all specimens against *S. aureus* and *E. coli*. It can be seen that the wool fabrics treated with colloidal nano silver had good antibacterial effect against *S. aureus* and *E. coli* by 20 times washing.

TABLE-1
ANTIBACTERIAL EFFECT (%) OF NANO-SILVER COLLOIDS ON WOOL FABRICS SAMPLES BEFORE AND AFTER WASHING

Washing time	Wool fabric treated with nano-silver (800 ppm)		Wool fabric treated with nano-silver (400 ppm)		Wool fabric treated with nano-silver (200 ppm)	
	S. aureus	*E. coli*	*S. aureus*	*E. coli*	*S. aureus*	*E. coli*
Before washing	99.9	99.9	99.9	99.9	99.9	99.9
After 5 cycles	99.5	99.9	98.2	99.9	98.8	99.2
After 10 cycles	98.7	99.5	97.7	99.2	97.2	98.9
After 20 cycles	97.9	99.2	96.9	98.5	96.7	98.5

The fiber surfaces of antibacterial treated fabrics were observed by SEM micrographs. In Fig. 2, SEM images show the nanoscales silver particles on wool fabrics. The silver nanoparticles are well dispersed on these surfaces.



(a) (b) (c)

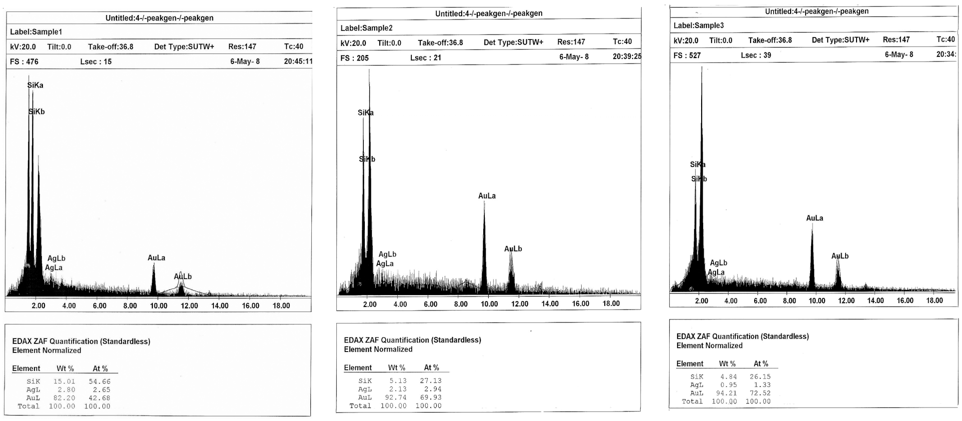
(d) (e) (f)

Fig. 2. SEM micrograph of wool fabric treated with nano silver: (a) 800 ppm at 625x, (b) 400 ppm at 937x, (c) 200 ppm at 1000x, (d) 800 ppm at 250x, (e) 800 ppm at 500x and (f) 200 ppm at 500x

The characteristic peaks for different element in the functional layer are presented in EDAX spectra, which were obtained for the surface of samples shown in Fig. 3. It can be seen that the per cent of nanosized silver particles increased on the surface of samples with increase concentration of colloid solutions nano silver.

Conclusion

This study has shown the antibacterial properties of nanosized silver colloidal solution against *S. aureus* and *E. coli* when we padded the solution on wool fabrics.The antibacterial efficiency was ever 96 % after 20 washing time. SEM



(a) (b) (c)

Fig. 3. EDAX spectra pattern of wool fabric treated with nano silver: (a) 800 ppm, (b) 400 ppm and (c) 200 ppm

images shown the nano silver particles were well dispersed on samples. The results were obtained for the surface of samples shown that the per cent of nanosized silver particles increased on the surface of samples with increase concentration of colloid solutions nano silver.

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